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Booster Neutrino Beamline Upgrade

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(presenting the work of Zarko Pavlovic & Tom Kobilarcik)

WINP

Thu Feb 5 2015

Booster Neutrino Beamline and Detectors



MiniBooNE

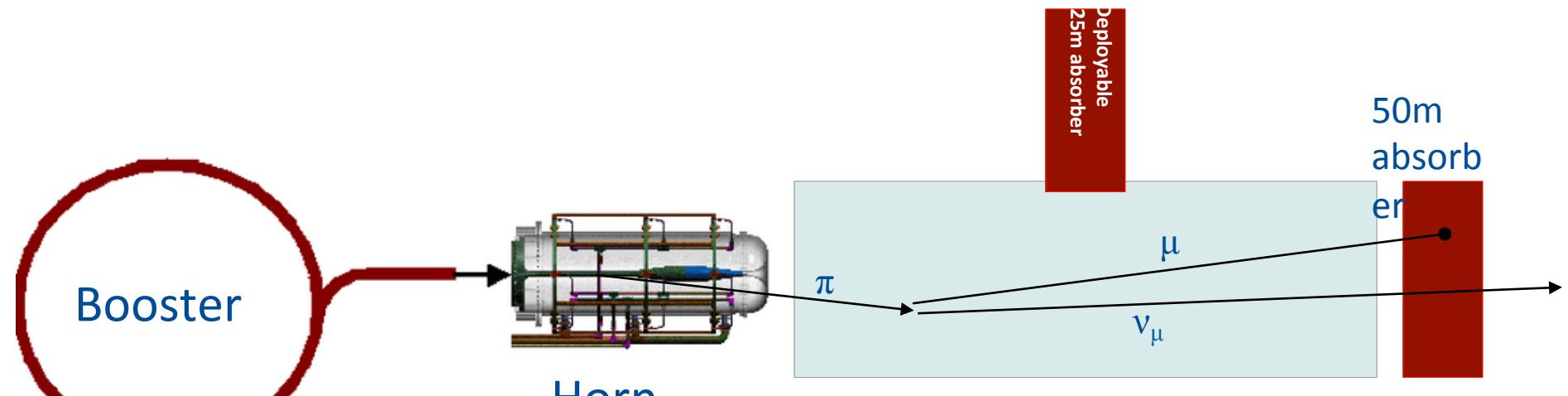
MicroBooNE

Booster

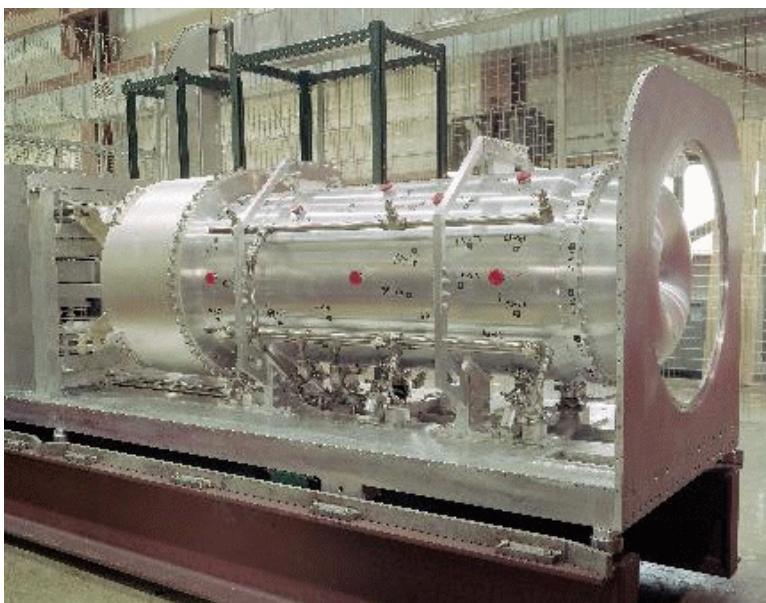
SciBooNE

Target Hall (MI12)

Booster Neutrino Beamlne



- 8 GeV protons from Booster
 - 4-5e12 PPP
 - Up to 5Hz average rate
- 1.7 int. length Be target
- Horn
 - Neutrino & Antineutrino mode $\pm 170\text{kA}$
- 50m long decay pipe



Why Upgrade

- The BNB is in great demand ...
 - Now - MicroBooNE
 - in the near future - SBN
 - and for the indefinite future – of 5 proposals presented at the last FNAL PAC meeting 4 were to put detectors in the BNB
- The BNB is a single horn system “built on a budget”
- The BNB was designed with constraints that can be relaxed for LAr detectors
 - High energy flux suppression needed by MiniBooNE for NC background suppression is not needed (at the same level) by LAr TPCs
- Significant flux increases ought to be possible

How to Upgrade

- Reoptimize the shape(s) of the horn inner conductor(s)
 - Current knowledge from the HARP experiment of pion production spectra from 8GeV protons on Be suggest reoptimizing the shape of the horn inner conductor
- Add a second horn (c.f. NuMI)
- Do it all for a “reasonable cost” – couple of \$M scale
 - Therefore try very hard to avoid any civil construction

Reoptimizing BNB (Z. Pavlovic)

- Feasibility study
- Work within existing beamline constraint (total length of system, transverse dimensions, decay pipe)
- Retune spectrum to maximize number of events

Fit parameters (Z.Pavlovic)

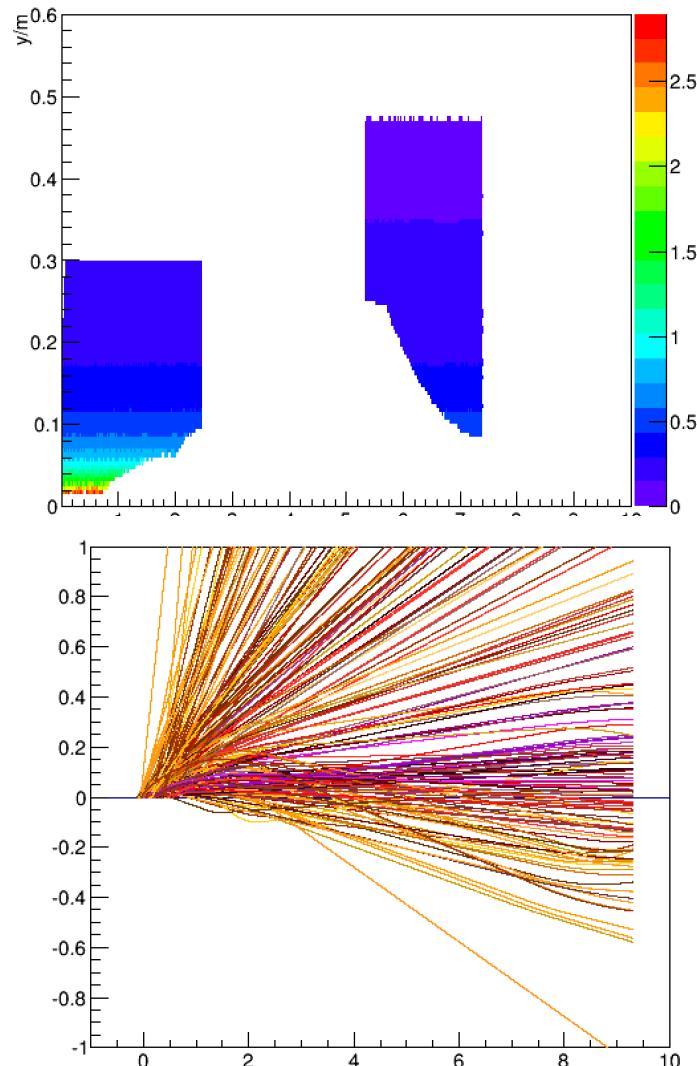
- Horn current (same current both horns)
- Target position
- Horn 1 length
- Horn 2 length
- Horn 1 shape - 7 parameters (3 segments - conical, parabolic, parabolic)
- Horn 2 shape - 5 parameters (2 segments - parabolic, parabolic)
- Horn 2 position

Parameter limits (Z. Pavlovic)

- Set ~realistic limits on parameters
 - Horn current <250kA (design limit for present PS)
 - Horn length 2.5m
 - Horn inner conductor $r>1.7\text{cm}$ (MiniBooNE horn 1.9cm)
 - Target pile up to 7m longer than present
- Fits prefer horn current, length, and inner conductor radius at limit

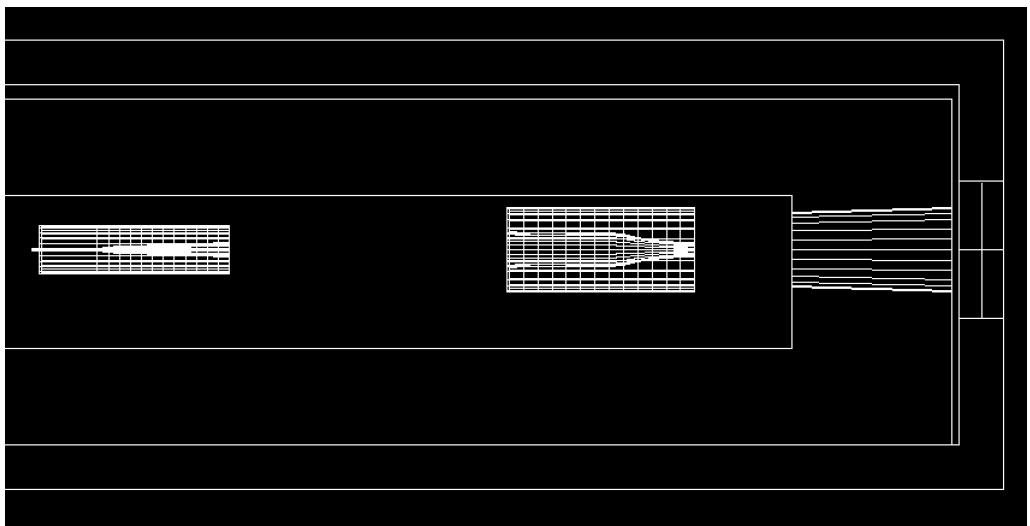
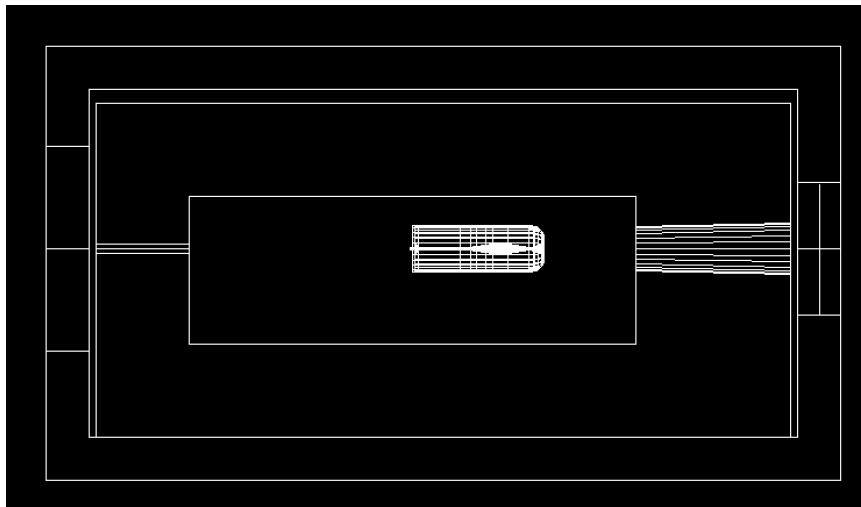
Fit technique (Z. Pavlovic)

- Fast MC to track pions through horn magnetic field
- Weight pions by product of
 - Probability for pion to decay in decay pipe (take into account collimator, decay pipe radius and length)
 - Probability of giving rise to a neutrino at detector (MicroBooNE location)
 - Neutrino Cross Section
- Maximize number of events in MicroBooNE



Full Beam MC simulation (Z. Pavlovic)

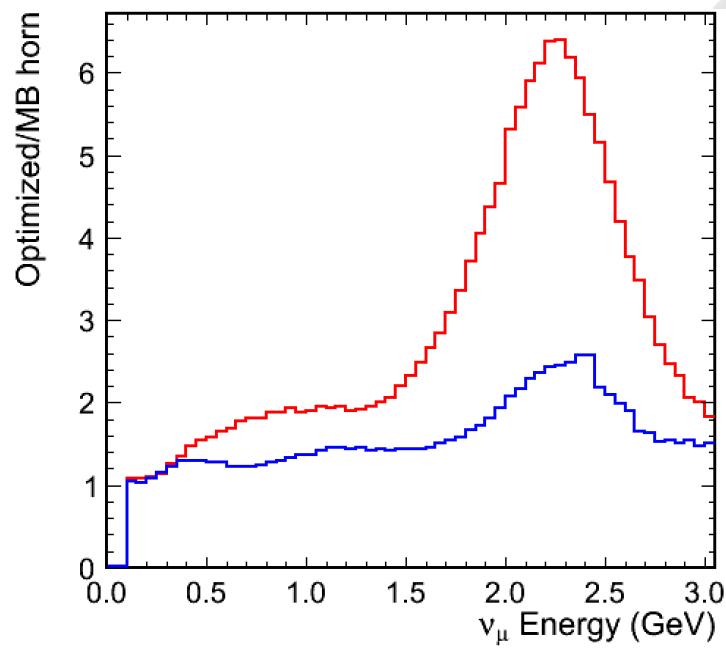
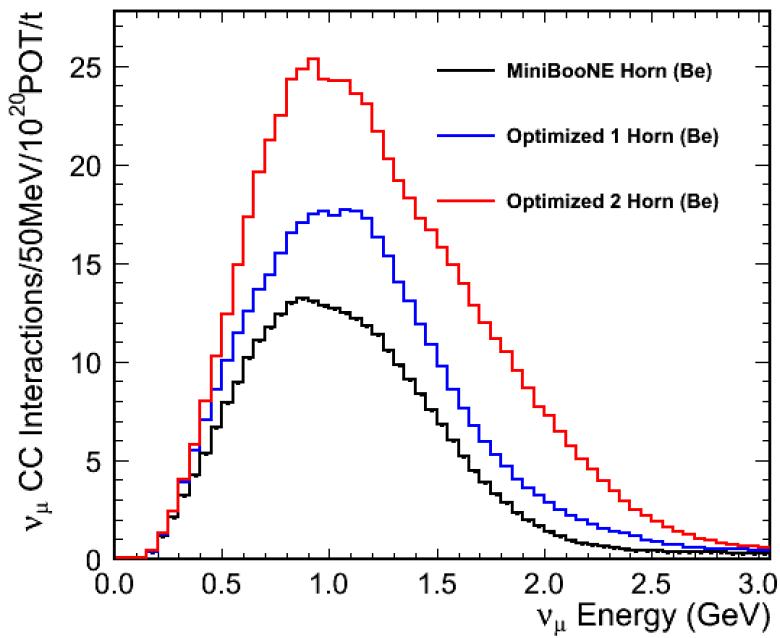
- Insert best fit horns into full BNB MC
- Best fit:
 - 2.5m long horns
 - 5.4m front of horn 1 to front of horn 2
 - 250kA
- Horn conductors same thickness as present MiniBooNE horn
- Target pile transverse dimensions the same
- Increase collimator radius ($0.3 \rightarrow 0.5\text{m}$) since second horn has bigger radius



Optimized vs Nominal Event Spectra (Z. Pavlovic)

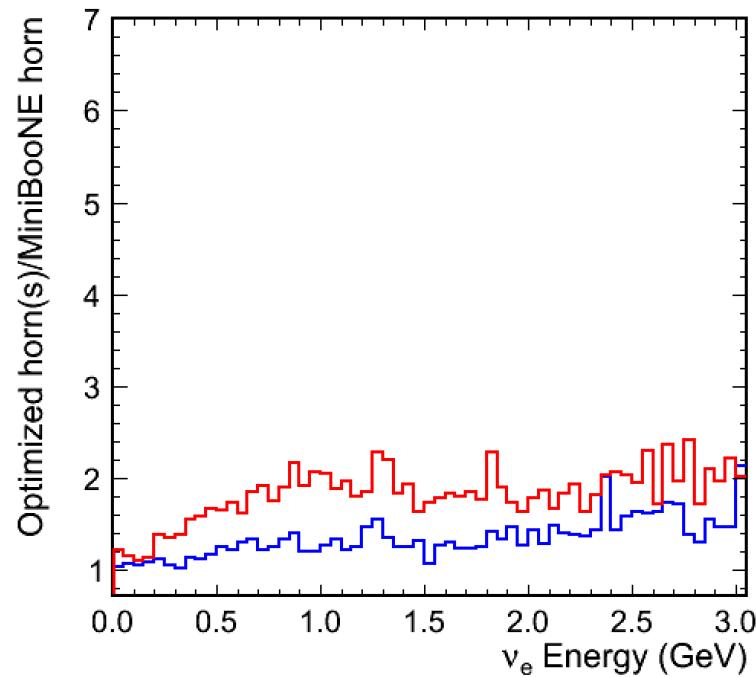
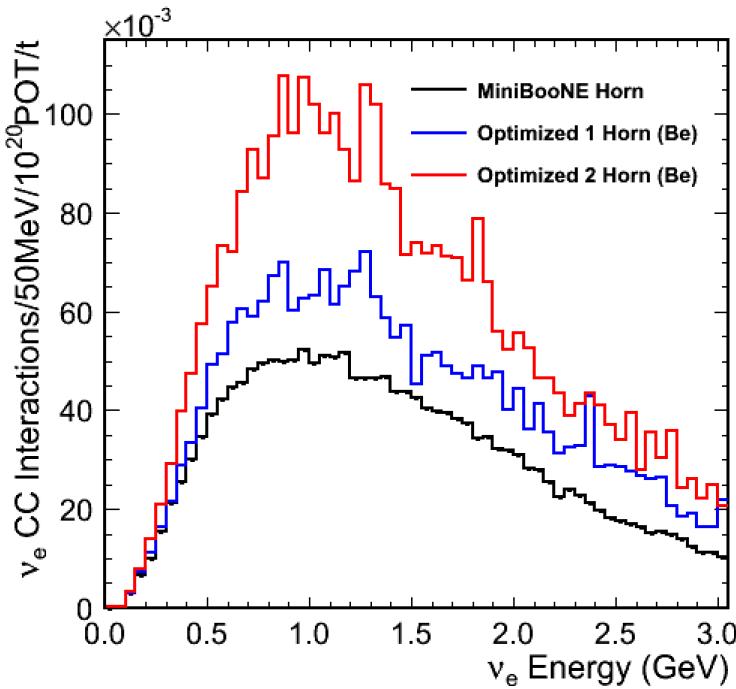
- Full beam MC

	CC (<i>Events/t/10²⁰POT</i>)	Flux ($\nu/m^2/10^6POT$)		
	MiniBooNE horn	2 horn	MiniBooNE horn	2 horn
ν_μ	302.0	636.6	7.02	12.6
$\bar{\nu}_\mu$	2.6	2.9	0.44	0.41
ν_e	2	3.8	0.039	0.067
$\bar{\nu}_e$	0.06	0.06	0.004	0.004



Intrinsic Nue Spectra (Z. Pavlovic)

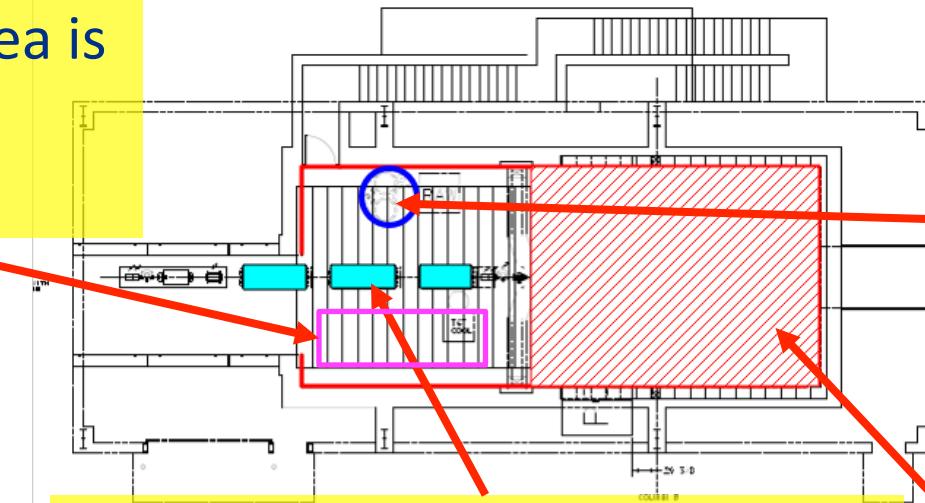
- For the optimized horn system the intrinsic nue background scales similarly to the numus at low energy
- Overall numus increased more than nues
- A 2nd horn would also significantly reduce the wrong-sign background in anti-neutrino mode



Making room for a 2nd horn (T. Kobilarcik)

- Shorten the primary beamline upstream of target
- Replace final focusing triplet with more compact system
- Remove/replace (downstream) collimator?

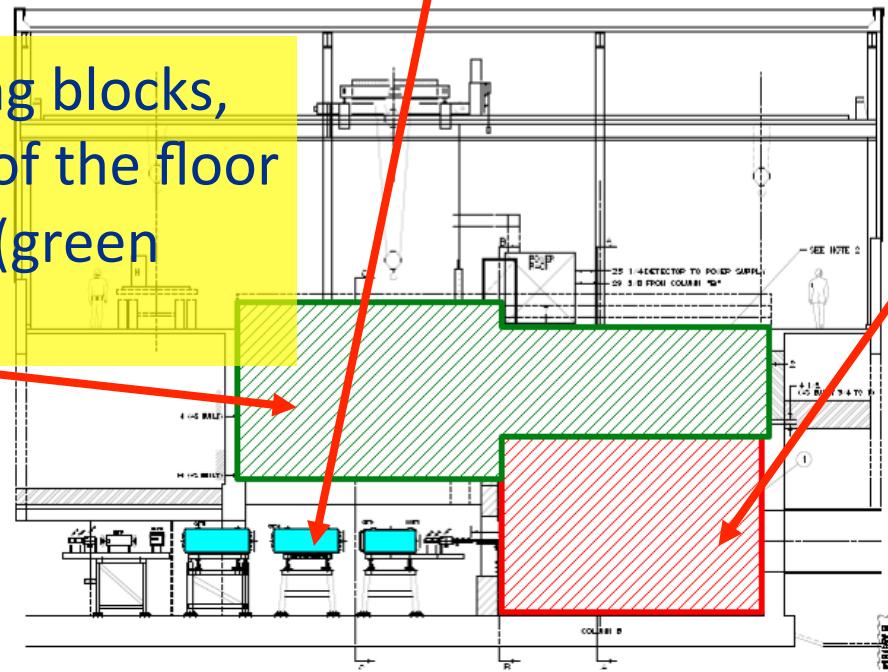
Most of this area is filled support infrastructure



Sump pit
(blue circle)

Final focusing triplet (light blue)

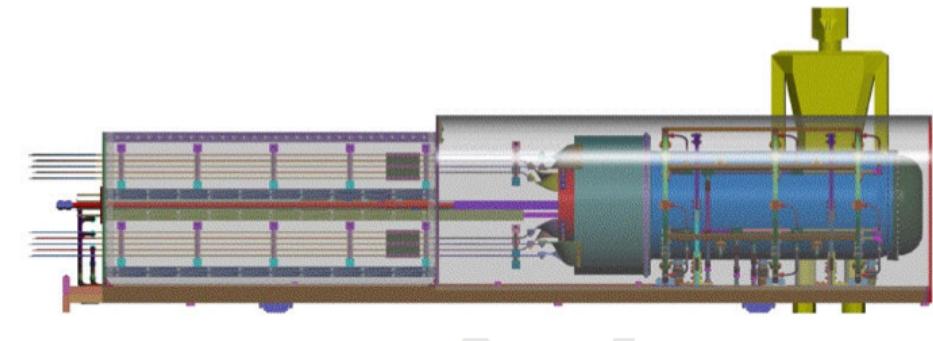
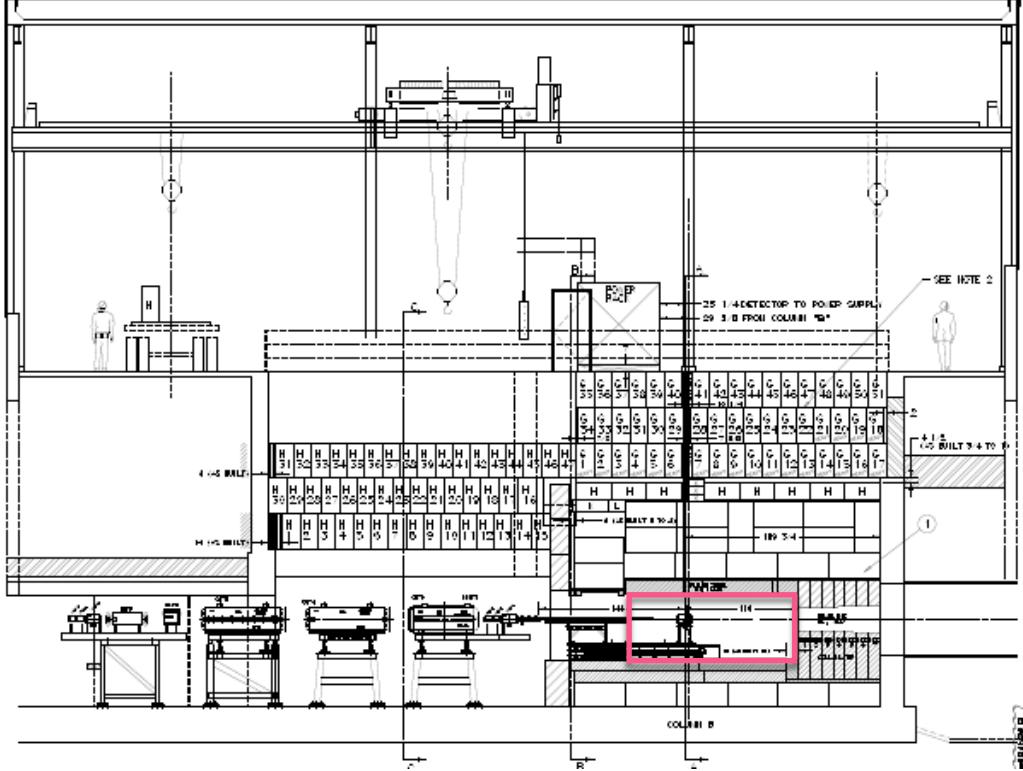
Concrete shielding blocks,
which form part of the floor
of the enclosure (green
hatch)

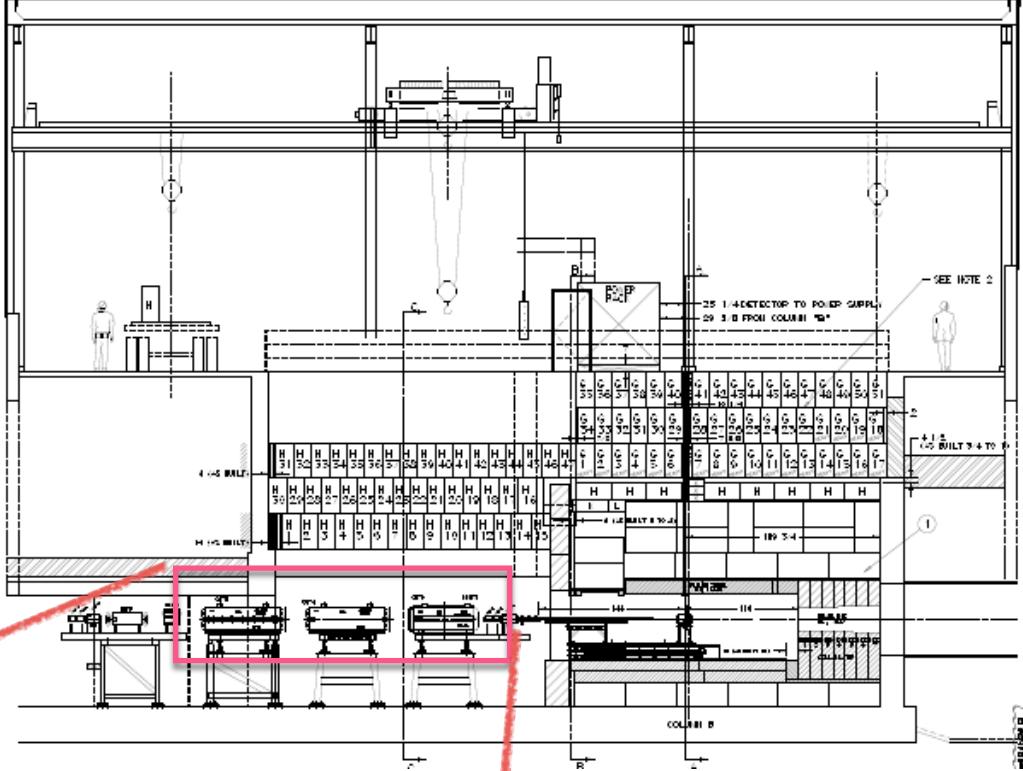


Steel shielding
(red hatch)

BNB Target Hall

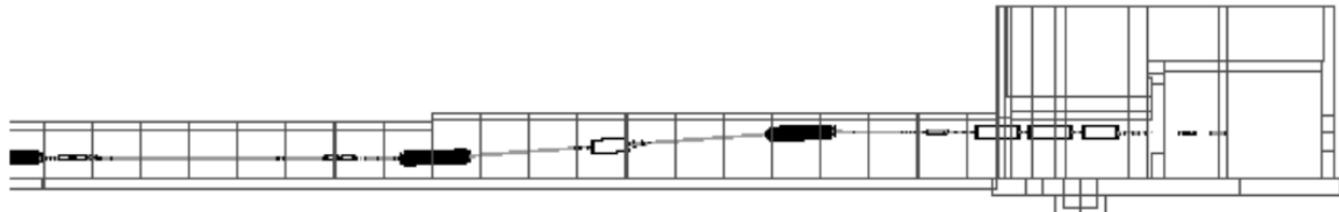




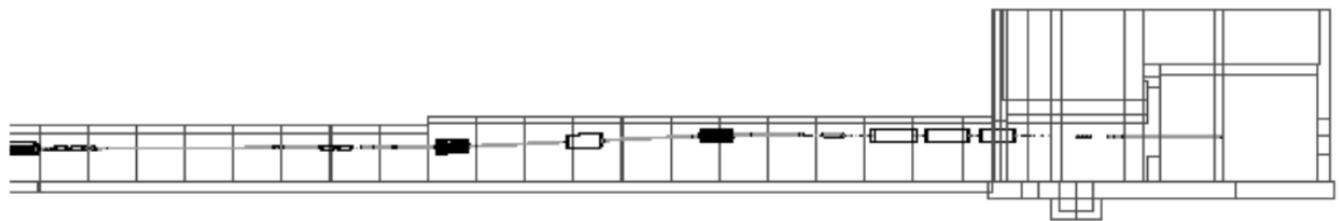


Shorter Proton Beamline (T. Kobilarcik)

- Shorter dogleg with slow upward movement of the beamline

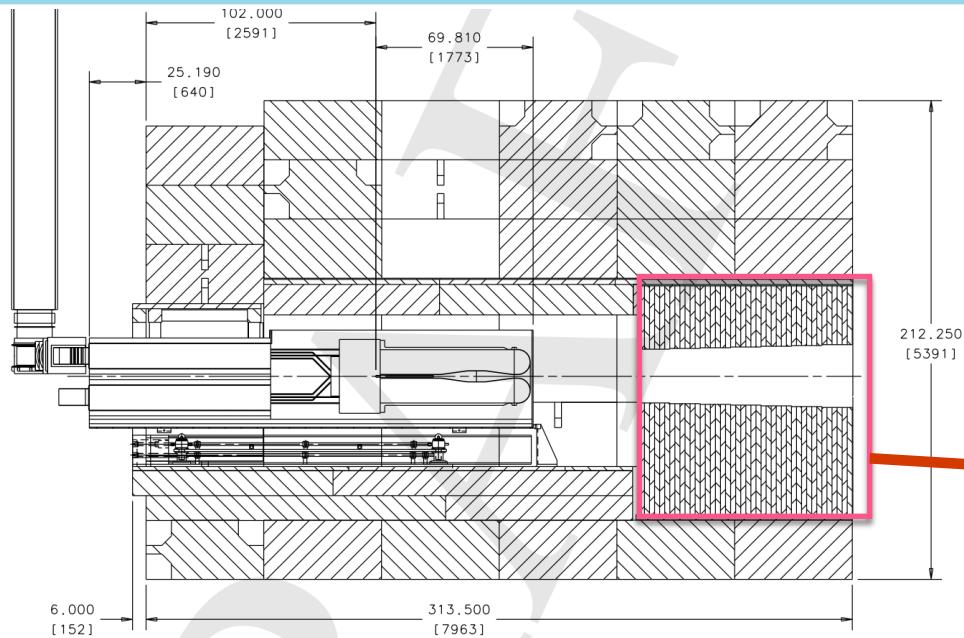


Current



Proposed

Redoing/Removing the Collimator? (T. Kobilarcik)



- Collimator is 2.14m long
- Flared shape 30cm upstream 32.5 downstream
- Stop hadrons that would hit decay pipe wall
- At present well below radiation limits
(unprotected ground surrounding decay pipe)
-> revisiting studies



Summary

- An upgraded BNB with 2 horns would double the neutrino count rate in all detectors

	CC ($Events/t/10^{20} POT$)		Flux ($\nu/m^2/10^6 POT$)	
	MiniBooNE horn	2 horn	MiniBooNE horn	2 horn
ν_μ	302.0	636.6	7.02	12.6
$\bar{\nu}_\mu$	2.6	2.9	0.44	0.41
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- The reoptimized system has reasonable parameters (2.5m long horns, 250kA, total length)

Summary

- There are several ways to create the necessary space in the target pile
 - Shorted the primary beam
 - Replace the final focusing triplet
 - Replace/remove collimator
- Upgraded system needs to be capable of making full use of future proton source upgrades
 - 15 Hz Booster running in ~2016
 - Possible 20 Hz running with PIP II
 - Higher power than the current 32kW maximum
- Next step: Produce a conceptual design report in time for the June FNAL PAC meeting

Backups

Protons on BNB target

	Now	PIP (>2016)	PIP II (>2023)
Booster cycles (Hz)	7.5	15	20
Protons/spill	4.5E+12	4.5E+12	6.5E+12
p/hr/Hz	1.6E+16	1.6E+16	2.3E+16
p/year/Hz	1.4E+20	1.4E+20	2E+20

No shutdowns (100% uptime)

- Sensitivities shown yesterday assumed 6.6e20POT
(2x6.6e20 in MicroBooNE)
- How many Hz can BNB take?

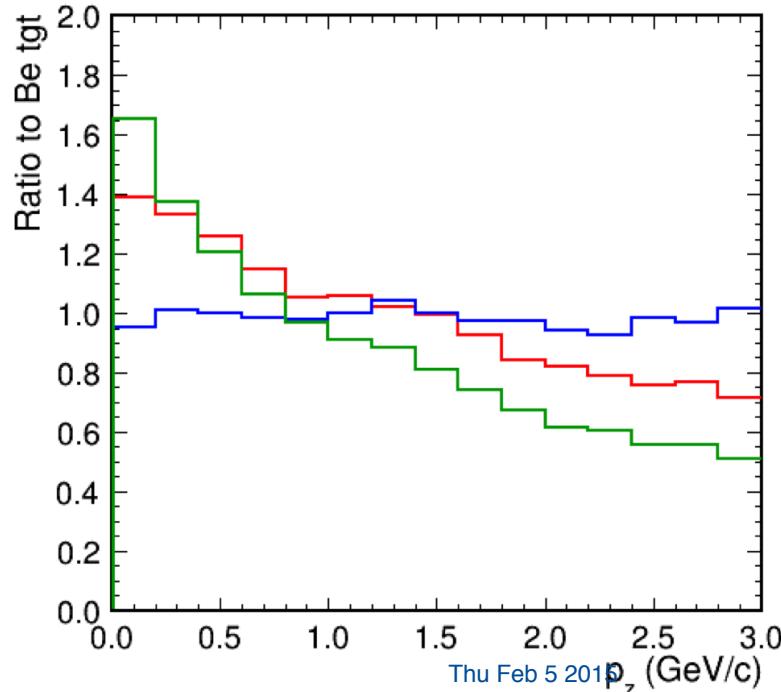
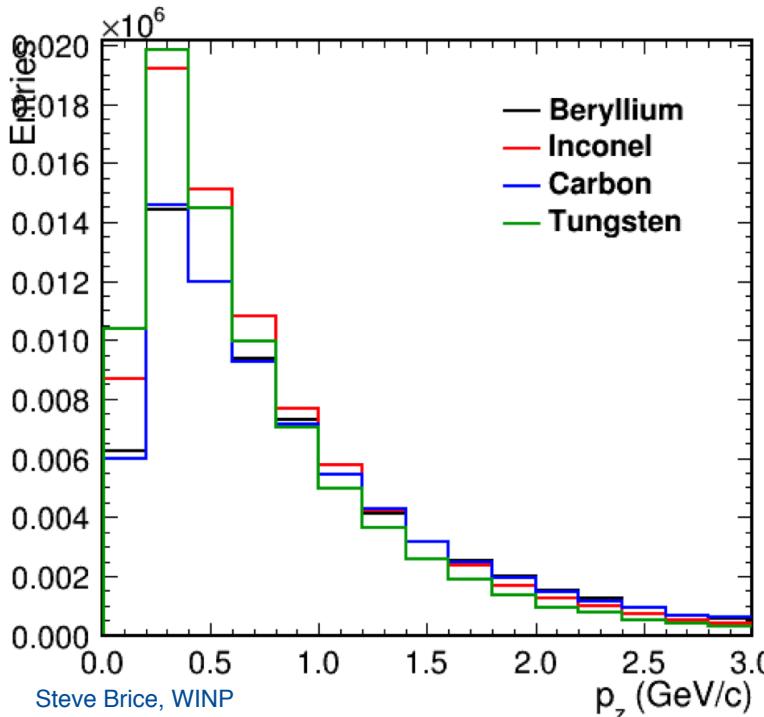
Current Limits

	Limit	Note
Horn	5 Hz	Average rate
Horn PS	7.5 Hz	
Booster & 8GeV Line up to cell 803	1.8e17/hr	Overburden
8 GeV Line (cell 803 to cell 850)	2.84e17/hr	Overburden
8 GeV Line (cell 850 to BNB target station)	1.62e17/hr	Overburden
BNB Target Station	7.5e20/year	Groundwater

- $4.5 \times 10^{12} \times 1 \text{ Hz} = 1.6 \times 10^{16} \text{ /hr} = 1.4 \times 10^{20} \text{ /year}$ (100% uptime)

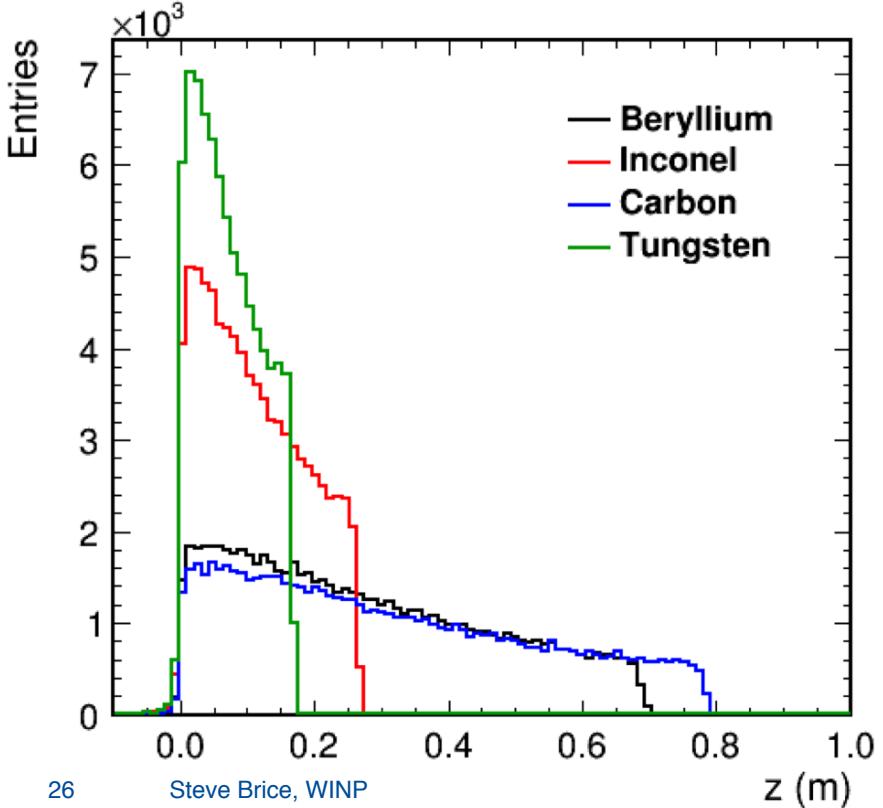
Target material

- Additional handle on spectrum?
- Heavier targets
 - more low momentum pions
 - shorter - more narrow band focusing



Target material

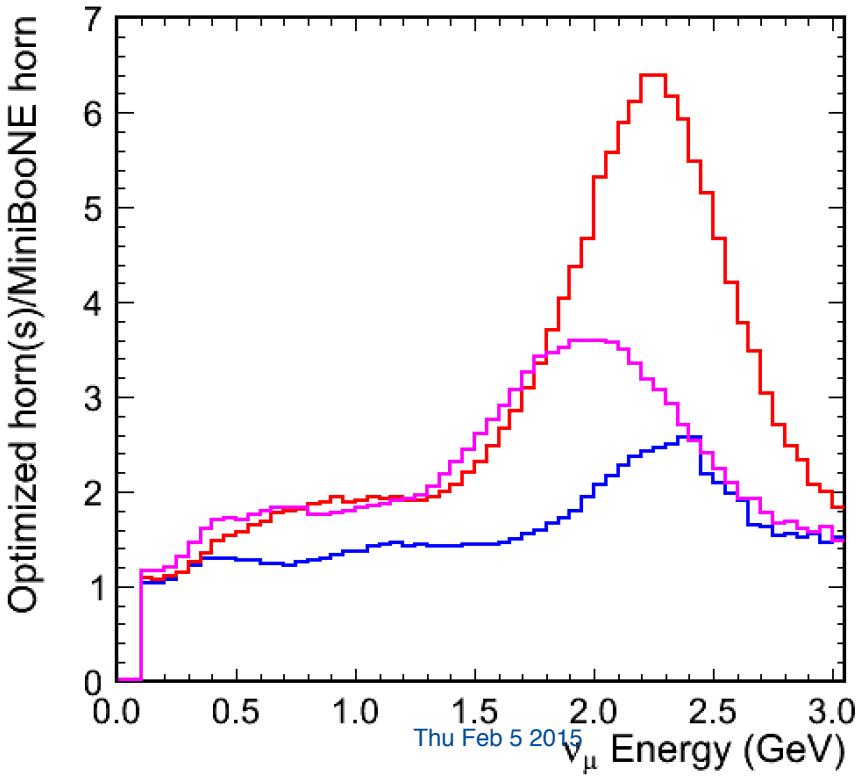
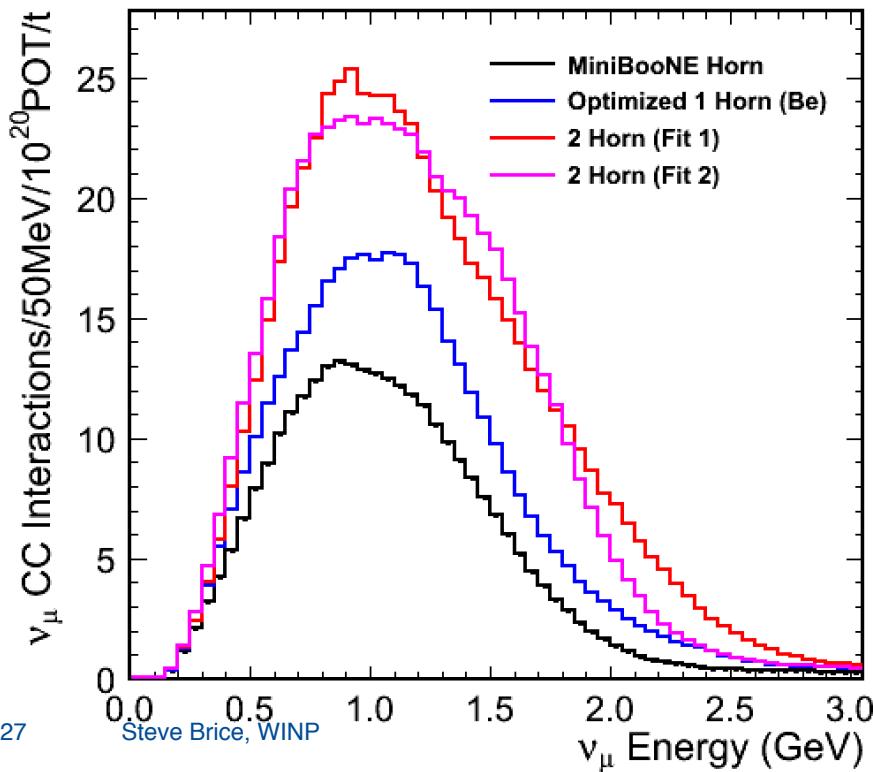
- Shorter targets allow more narrow band focusing



	68	1
	78	0.99
	26	1.13
	16	1.08

Sculpting the spectrum

- Lots of room for fine tuning
- Use different FOM to tune specific part of the spectrum
- Need more realistic sensitivities for re-optimized configuration



Sump pit

